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Correlates of lifestyle patterns among children in Singapore aged 10 years: the growing up in Singapore towards healthy outcomes (GUSTO) study

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Abstract

Objective To characterise lifestyle patterns (comprising dietary and movement behaviour aspects) of children in Singapore and examine the correlates of these patterns.

Design An observational study approach was used. Children recorded their diet and activities over two weekdays and two weekend days on a validated web-based assessment, My E-Diary for Activities and Lifestyle (MEDAL). Lifestyle patterns were derived using principal component analysis, and the correlations of these with multiple known determinants organised by distal, intermediate, and proximal levels of influence were studied.

Setting Children of the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort.

Participants Ten-year-old children ($n = 397$).

Results Three lifestyle patterns, "high snacks and processed food", "balanced" and "mixed", were identified. We focused on the more health-promoting "balanced" pattern, characterised by lower screen-viewing and higher consumption of fruits, vegetables, wholegrains, and dairy. Among the distal factors, girls were more adherent to the "balanced" pattern compared to boys, and children of parents with lower education levels were less adherent to this pattern. Among intermediate factors, children of mothers with higher diet quality were more adherent to the "balanced" pattern. Among the proximal factors, engagement in active transport, leisure sports, and educational activities outside of school were positively associated with the "balanced" pattern, whereas screen-viewing while travelling was negatively

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associated with this pattern. Having siblings, pet ownership, mother's physical activity, parenting style, parental bonding, child's outdoor time, and breakfast consumption were not associated with children's lifestyle patterns.

Conclusions These findings provide direction for future interventions by identifying vulnerable groups and contexts that should be prioritised.

Keywords Diet, Physical activity, Sleep, Screen-viewing, Lifestyle pattern, Children, Asia, Correlates

Introduction

Children's lifestyles, comprising diet and movement behaviours, have been associated with weight status and through this with health outcomes including metabolic diseases in childhood and later life [1]. Coupled with the tendency for these behaviours to track into adulthood [2], this population has been the target of early lifestyle interventions that aim to foster healthy lifestyle habits from childhood [3]. Developing evidence-based interventions first requires understanding these health behaviours and their correlates for potential targeting. However, lifestyle behaviours often do not occur exclusively, but rather coexist and influence health through complex, synergistic relationships [4–7], making it difficult to pinpoint a single, isolated behaviour that should be targeted.

Studies that have examined lifestyle behaviours collectively as lifestyle patterns have revealed integrated patterns of health behaviours, such as "unhealthy", "healthy", and "mixed" lifestyle patterns among children and adolescents across the ages of 5–19 years [4, 7–9]. Notably, in this population, "mixed" patterns highlight the co-occurrence of healthy and unhealthy behaviours (e.g. high physical activity and high sedentary behaviour, including screen time, and poor diet), reinforcing the need to consider multiple behaviours that collectively influence health [4, 7–9].

To date, the majority of existing studies have characterised the lifestyle patterns of children in Western populations, with Asian representation being limited to children in China and India aged 9–11 years [5]. Diet, environment, culture, and socio-political contexts that collectively influence lifestyle behaviours may differ by population, limiting the generalisability of these findings to children of other regions [3]. One study conducted in the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort has examined both dietary and movement behaviour aspects of younger children in Singapore aged five years and characterised their lifestyle patterns [10]. However, given that significant changes in lifestyle behaviours may occur as children get older, such as becoming more sedentary, engaging in longer screen-viewing, and developing increasingly unhealthy eating habits with age [11, 12], findings from children of a younger age group cannot be extrapolated to explain the lifestyle patterns of older children, thus requiring a separate study to bridge this knowledge gap.

Understanding the lifestyles of children can help identify groups of children at risk of less healthy lifestyles and the associated contexts. Studies to date have identified various factors associated with the lifestyle habits of children, including socioeconomic status (SES) [8], parenting practices [13], parent-child relationships [14], and parental reinforcement or support towards health behaviours [15]. Other equivocal factors that may be associated with children's lifestyle and warrant further research include pet (specifically, dog) ownership as pets offer social support and opportunities for physical activity [16]; having siblings who could act as role models for health behaviours [17]; and emerging health behaviours like screen time multitasking that have been associated with other unhealthy behaviours [18]. Despite the myriad of factors concurrently and collectively influencing the lifestyle behaviours of children, many do not explain or account for how these factors interrelate. In studies which investigate multiple correlates of children's lifestyle behaviours using traditional regression methods (i.e. a single multivariable model), distal (or upstream, e.g. SES), intermediate, and proximal influences (has most direct influence, e.g. context in which children's daily activities occurred) of children's lifestyle are treated as equals that are mutually adjusted for in the same model, resulting in the underestimation of the effect of distal factors and inflation of the effect of downstream factors on children's lifestyles [19].

One way to account for the interrelated covariates is to adopt a hierarchical analytical approach, where covariates to be included in models are selected based on an established conceptual framework that describes the relationship between these variables. These variables are organised based on their level of influence on the outcome and are adjusted in separate models accordingly. This way, covariates can be interpreted more accurately, allowing for a better understanding of the effects of these factors on children's lifestyle patterns.

With these in mind, the present study aimed to bridge the literature gap by (1) characterising the lifestyle patterns of ten-year-old children in the GUSTO cohort using principal component analysis, and (2) examining a range of factors that may be associated with these children's lifestyle patterns using a hierarchical regression analysis approach.

We hypothesised that the lifestyles of children aged 10 years from the GUSTO cohort would be associated with specific sociodemographic, parent- and child-related factors. Such findings would provide valuable information on the characteristics of the lifestyles of older children in Asian populations and shed light on vulnerable groups that should be prioritised for future interventions.

Methods

Study population

This is an observational study nested within the GUSTO birth cohort study. To provide context, GUSTO is an on-going multi-ethnic birth cohort which commenced in 2009 to investigate the associations between early life factors and the health and development outcomes of children; details of the cohort have been published previously [20]. In brief, pregnant women were recruited from two major public maternity units in Singapore: KK Women's and Children's Hospital, and National University Hospital. Women who were aged at least 18 years, of Chinese, Malay, or Indian ethnicity with a same-ethnicity partner, Singapore citizens or permanent residents, and were intending to deliver in one of the two above-mentioned maternity units and remain in Singapore for the following 5 years were eligible. Of 1450 women recruited, 1219 babies (including 10 twin-births) were born and followed up regularly. For the current study, data from child participants at 10 years of age were analysed. This study was approved by the National Healthcare Group Domain Specific Review Board and the SingHealth Centralised Institutional Review Board, and all participants provided written informed consent at enrolment.

Data collection

Lifestyle information of children

My E-Diary for Activities and Lifestyle (MEDAL), a web-based lifestyle assessment application developed to collect time-use information was administered to collect self-reported lifestyle behaviour information. Details of the development, usability, and validity of the MEDAL application have been published [21–23].

During the clinic visit at 10 years, a trained researcher explained the MEDAL interface to the participant and allowed him or her to record the activities he or she did and everything he or she ate the day before the day of the clinic visit. The participant could clarify any difficulty they faced when using MEDAL during the clinic visit. Participants were instructed to complete the entry at home, and to record their diet and activities on MEDAL from the time they woke up to the time they went to bed in chronological order over two specified weekdays and two weekend days independently, without assistance from their parents or caregivers. These entries capture information related to their diet and movement behaviours, such as portion size of food and drinks consumed, duration and intensity of activities they engaged in, and whether any other activity occurred concurrently (e.g. screen-viewing during a meal).

The data collected via MEDAL were processed to generate information on averaged daily moderate-to-vigorous physical activity (MVPA), screen-viewing, and sleep, and averaged daily intakes of fruits, vegetables, wholegrains, dairy, sugar-sweetened beverages (SSB), sweet and savoury snacks, fast food, and processed food (i.e. ham or luncheon meat, instant noodles, nuggets, sausages, and meatballs). This was done by dividing total reported time spent in each of these behaviours or intakes by the number of days recorded on MEDAL by each participant (range: 2 to 4 days). These variables were selected in accordance with the Singapore Integrated 24-hour Activity Guidelines for Children and Adolescents, which have been identified as important for optimising the health and well-being of children [24]. Engagement in MVPA, screen-viewing, and sleep were expressed in minutes or hours. Intakes of fruits, vegetables, dairy, and SSB were expressed in servings in accordance with the local Health Promotion Board's quantification of one serving for items in these food groups [25]. As what constitutes one serving of wholegrains, sweet and savoury snacks, fast food, and processed food were not available, we presented these variables based on the average daily frequency in which they were consumed.

Outliers were replaced with the maximum values of the acceptable distribution, i.e. value at 99th percentile of the distribution [10]: movement behaviour-related behaviours with values above the 99th percentile were replaced for MVPA (207.5 min, $n=3$), screen-viewing (13.0 h, $n=3$), and sleep (13.0 h, $n=4$). Diet-related variables with values above the 99th percentile were replaced for fruits (2.5 servings, $n=3$), vegetables (3.3 servings, $n=3$), wholegrains (2.3 times consumed per day, $n=4$), dairy (1.4 servings, $n=3$), SSB (3.8 servings, $n=3$), sweet and savoury snacks (3.0 times consumed per day, $n=2$), fast food (2.0 times consumed per day, $n=1$), and processed food (2.5 times consumed per day, $n=2$).

Family sociodemographic, parent- and child related variables

To examine the correlates of children's lifestyle patterns, we selected variables with guidance from the Family Ecological Model [26] that were available in the GUSTO study and hypothesised to be associated with children's lifestyles. These variables were grouped as distal, intermediate, and proximal in terms of level of influence on lifestyle patterns respectively (Fig. 1). Details of each variable are available in Supplementary Table 1.

In brief, distal factors (i.e. family sociodemographic) included variables such as child's sex, child's ethnicity, maternal marital status when the child was 8 years,

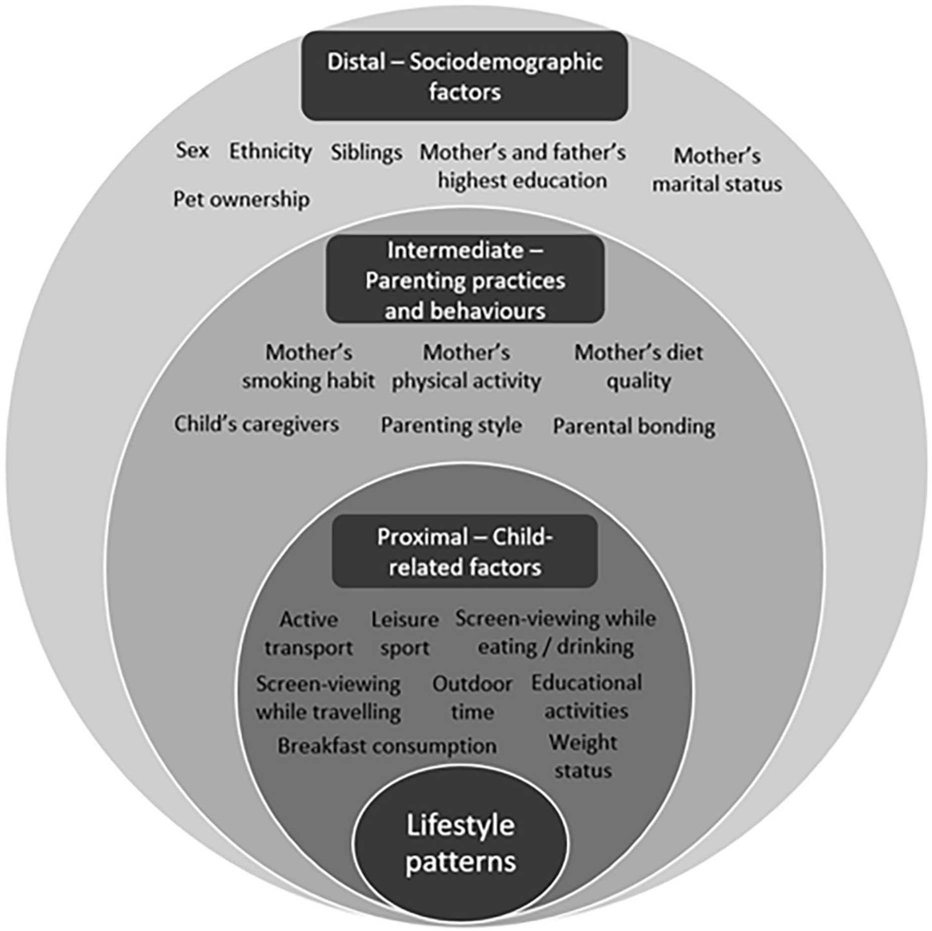

Fig. 1 Conceptual framework of distal, intermediate, and proximal factors examined in association with children's lifestyle patterns in the present study

whether the child had siblings when the child was 8 years, maternal and paternal education level when the child was 5 years, and pet ownership when the child was 7 years, were collected through questionnaires administered by interviewers to mothers of children in the GUSTO cohort between 5 and 8 years.

Intermediate factors (i.e. parenting practices and health behaviours) included variables such as self-reported maternal smoking habits, physical activity, and diet quality (scored using a diet quality index based on completed food frequency questionnaires) when the child was 10, 8, and 6 years respectively, and the identity of caregivers of the child when the child was 10.5 years, collected using and/or derived from questionnaires administered to mothers of the GUSTO child participants. For the present study, we defined caregivers as someone who spent at least two hours with the child in a week and was responsible for certain aspects of the child's daily routine. We then categorised caregiver information as whether the child was cared for by their parents only, or by a combination of their parents and another caregiver (e.g. grandparents, domestic helper, and others). Mothers reported their own parenting style as well as their perception of their partner's parenting style using the Parenting Styles and Dimensions Questionnaire Short Form (PSDQ) [27] when their child was 8.5 years. Parental bonding between parent and child, defined as how caring and overprotective the child perceived their mother and father to be, was collected using the Parental Bonding Instrument (PBI) [28] administered to the child when they were 8.5 years.

Proximal factors included variables that had most direct relationship with children's diet and movement behaviours. This included their weight status based on height and weight measurements obtained during their follow up visit at age 10 years, and contextual activities they engaged in, obtained from the child's MEDAL entries. For the present study, we classified children as being underweight, of healthy weight, and overweight based on population-derived sex- and age-specific percentiles [29]. Contextual activities were defined as activities that happened in specific contexts (e.g. time of day, location, type, or situation), such as active transport (i.e. walking or cycling), leisure sports (i.e. engagement in sports that did not occur in school and were assumed to be for leisure), screen-viewing while travelling or during an eating or drinking occasion, outdoor time, educational activities (i.e. reading, studying, or enrichment lessons that did not occur in school), and breakfast consumption.

Statistical analysis

Participants who recorded at least two days on MEDAL with at least two meals (i.e. breakfast, lunch, or dinner) each day were included for analyses. Due to high homogeneity in variables relating to maternal marital status (95.5% married) and maternal smoking habit (94.5% non-smoker), these variables were excluded from subsequent analysis. Test for differences in characteristics between included and excluded participants were performed using Pearson's chi-squared test and two-sample t-test for categorical and continuous variables respectively. To provide some description of the lifestyle behaviours of children, we present the mean and standard deviation (s.d.) for 11 lifestyle behaviours, i.e. durations of MVPA, screen-viewing and sleep, and intakes (servings or frequency) of fruits, vegetables, wholegrains, dairy, SSB, sweet and savoury snacks, fast food, and processed food. We further stratified these results by sex and compared girls and boys using two-sample t-tests.

We derived the lifestyle patterns of the participants using principal component analysis (PCA) with varimax rotation on the 11 lifestyle behaviours. Among two methods of rotation we are familiar with, the orthogonal varimax rotation produced slightly more interpretable PCs, thus guiding our current approach. Three orthogonal patterns were retained based on eigenvalues (>1.0), an inspection of the scree plot, and pattern interpretability [10]. Scores for each lifestyle pattern were generated for each participant by summing the 11 input variables and multiplying these by the corresponding loadings of each input variable. A higher pattern score indicates higher adherence to the lifestyle pattern. These patterns were characterised by variables that had loadings greater than 0.25, a cut-off that has been applied and accepted previously [10, 30].

To examine the associations between factors of distal, intermediate, and proximal levels of influence on lifestyle patterns, we first imputed missing distal and intermediate-level factors (no missing proximal-level factors) to maximise power. Linear regression, logistic, ordered logistic, and multinomial logistic methods were used to impute missing continuous, binary, ordinal, and nominal variables respectively, assuming these data were missing at random (MAR). This assumption was ascertained by taking each column with missingness and recoding as "1" for not missing and "0" otherwise. We then regressed each variable on each other using logistic regression where all associations returned significant ($p<0.001$), suggesting that our data were MAR. Using the Markov chain Monte Carlo method, 45 datasets were imputed [31]. Estimates and standard errors across the imputed datasets were pooled using Rubin's Rules [32]. The 95% confidence intervals were estimated, and p-values were obtained from these pooled estimates. To inform our model building, we performed simple linear regression analyses between each of the exposure variable and each lifestyle pattern and only included variables with $p<0.10$ in the subsequent multivariable regression analysis (results are available in Supplementary Table 2); for categorical variables with more than 2 groups, overall p-values were evaluated.

In the multivariable regression analysis, each component of the conceptual framework that returned significant in the univariate analysis was entered into the regression model in a hierarchical manner (Fig. 1) starting with the factors of distal, intermediate, then proximal level of influence on the outcome of interest (i.e. children's lifestyle pattern at 10 years) [10, 19]. The first model (Model 1) regressed distal variables on the lifestyle patterns. The second model (Model 2) further included the intermediate variables in addition to variables that returned significant in Model 1 (at $p<0.05$), and the third model (Model 3) further included the proximal variables in addition to variables that returned significant in Model 2 (at $p<0.05$). In these multivariable analyses, each variable was interpreted within the first model in which it was included, independent of the significance of the association between the variable and lifestyle pattern in subsequent models. Sensitivity analyses were performed to evaluate if imputation of missing data may have altered our conclusion, once by excluding variables with large proportion of missing data (i.e. variables relating to caregiver information, parenting style, and parental bonding with 40–44% missingness), and a second time by performing the hierarchical regression analysis on participants with complete data.

All statistical tests were performed using Stata Special Edition version 14.2 (StataCorp LP, USA). All evaluations were made assuming a two-sided test at 5% level of significance unless otherwise specified.

Results

Characteristics of study sample

Of 683 children in the GUSTO cohort we recruited to participate in the MEDAL recording at 10 years, 600 children agreed and attempted recording on MEDAL. Among them, those who recorded less than two valid days on MEDAL ($n=203$) were excluded; the final sample included for analysis was made up of 397 children (including one twin-pair), which represented 66% of the children who recorded on MEDAL (Fig. 2). Included and excluded participants differed in several characteristics, specifically, included participants were more likely to be

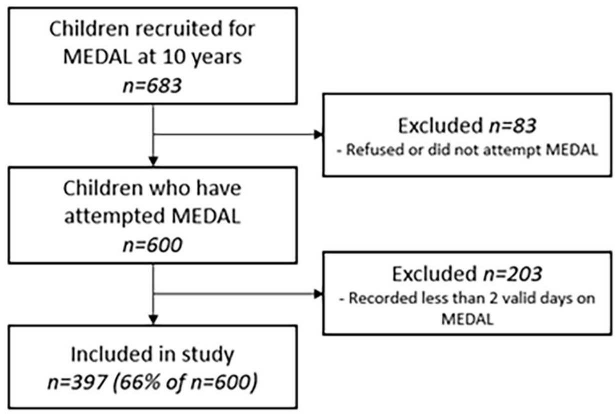

Fig. 2 Flowchart of participants included in the present study

of Chinese ethnicity, born to parents of higher education attainment, own pets, and have mothers who were insufficiently active (Supplementary Table 3).

Around half of the included sample were girls (52.1%), 66.8% were of Chinese ethnicity, 78.2% had a healthy weight (8.7% underweight, 13.1% overweight), 84.5% had siblings, 61.1% of mothers and 45.7% of fathers had at least degree-level education, and 85.9% had no pets. Their mothers tended to be sufficiently active (52.1%), and these children tended to be cared for by their parents only (53.8%) (Supplementary Table 3).

The descriptives for engagement in MVPA, screen-viewing and sleep, and intakes of fruits, vegetables, wholegrains, dairy, SSB, sweet and savoury snacks, fast food and processed food are summarised in Table 1. Boys spent more time screen-viewing compared to girls, and had lower intakes of fruits and vegetables, sweet and savoury snacks, and processed foods compared to girls.

Lifestyle patterns identified from study sample

Based on the PCA, three lifestyle patterns emerged. The first pattern was characterised by higher intakes of sweet and savoury snacks and processed foods and was named the "high snacks and processed food" pattern. The second pattern was characterised by lower engagement in screen-viewing, and higher intakes of fruits, vegetables, wholegrains, and dairy, and was named the "balanced" pattern. The third pattern was characterised by higher engagement in MVPA but lower intakes of vegetables, and higher intakes of SSB and fast food. Due to the coexistence of healthy and unhealthy behaviours, this pattern was named the "mixed" pattern. These patterns accounted for 18.0%, 16.3%, and 13.9% of the explained variance respectively. The factor loadings are presented in Supplementary Table 4.

Associations between adherence to lifestyle patterns and various distal, intermediate, and proximal factors

The lifestyle patterns were associated with several distal (i.e. child's sex, ethnicity, and parent's education level), intermediate (i.e. maternal diet quality and child's caregiving arrangement), and proximal (i.e. child's engagement in active transport, leisure sports, screen-viewing while travelling or when eating or drinking, and educational activities) factors; there were more distal and proximal factors associated with adherence to the lifestyle patterns, compared to intermediate factors (Table 2).

Among the distal factors, girls were more adherent to the "high snacks and processed food" (β=0.47, 95% CI 0.20, 0.75) and "balanced" pattern (β=0.42, 95% CI 0.17, 0.67) compared to boys. Children of mothers (β=-0.56, 95% CI -1.00, -0.13) and fathers (β=-0.49, 95% CI -0.91, -0.08) of lower educational attainment were less adherent to the "balanced" pattern compared to children of mothers and fathers with higher educational attainment. Children of Malay ethnicity (β=0.72, 95% CI 0.38, 1.05) compared to the children of Chinese ethnicity were more adherent to the "mixed" pattern. Having siblings and pet ownership were not associated with any of the lifestyle patterns.

Among the intermediate factors, children of mothers with higher diet quality (β=0.26 95% CI 0.001, 0.52)

Table 1 Mean (s.d.) durations of activities and food group intakes

	Mean (s.d.)	**Girls (*n*=207)**	**Boys (*n*=190)**	***p*-value**
MVPA, min/day	53.7 (46.2)	55.5 (49.9)	51.7 (41.7)	0.410
Screen-viewing, h/day	4.3 (2.6)	4.0 (2.5)	4.6 (2.7)	**0.022***
Sleep, h/day	9.9 (1.2)	9.9 (1.1)	9.8 (1.2)	0.341
Fruits, servings/day	0.3 (0.5)	0.4 (0.5)	0.3 (0.5)	0.110
Vegetables, servings/day	0.5 (0.6)	0.5 (0.7)	0.4 (0.5)	**0.019***
Wholegrains, frequency/day	0.2 (0.4)	0.2 (0.4)	0.2 (0.4)	0.454
Dairy, servings/day	0.2 (0.3)	0.2 (0.3)	0.2 (0.2)	0.453
SSB, servings/day	1.1 (0.9)	1.1 (0.9)	1.1 (0.9)	0.681
Sweet and savoury snacks, frequency/day	0.8 (0.7)	0.9 (0.8)	0.6 (0.6)	**<0.001**
Fast food, frequency/day	0.3 (0.4)	0.3 (0.4)	0.4 (0.5)	0.056
Processed food, frequency/day	0.6 (0.6)	0.6 (0.6)	0.5 (0.5)	**0.003***

Asterisks (*) denote statistically significant associations at 5% level of significance ($p<0.05$)

Table 2 Hierarchical regression analyses to study correlates of lifestyle pattern scores ($n=397$)

	"High snacks and processed food" pattern	"Balanced" pattern	"Mixed" pattern
Family sociodemographic (Distal factors)			
Sex			
Girls vs. boys	**0.47 (0.20, 0.75)***	**0.42 (0.17, 0.67)***	NIR
Ethnicity			
Malays vs. Chinese	NIR	-0.35 (-0.71, 0.01)	**0.72 (0.38, 1.05)***
Indians vs. Chinese	NIR	0.20 (-0.16, 0.57)	0.01 (-0.33, 0.36)
Siblings			
With siblings vs. only child	NIR	NIR	NIR
Maternal education			
Low vs. high	NIR	**-0.56 (-1.00, -0.13)***	-0.14 (-0.54, 0.26)
Mid vs. high	NIR	-0.21 (-0.57, 0.16)	0.34 (-0.002, 0.68)
Paternal education			
Low vs. high	NIR	**-0.49 (-0.91, -0.08)***	0.31 (-0.09, 0.71)
Mid vs. high	NIR	**-0.35 (-0.68, -0.01)***	0.11 (-0.22, 0.44)
Pets			
No pets vs. dog(s)	NIR	-0.003 (-0.61, 0.60)	NIR
At least one pet but no dog vs. dog(s)	NIR	-0.38 (-1.11, 0.36)	NIR
Parenting practices and behaviours (Intermediate factors)			
Mother's physical activity			
Insufficiently active vs. highly active	NIR	NIR	NIR
Sufficiently active vs. highly active	NIR	NIR	NIR
Maternal diet quality score			
High vs. low	NIR	**0.26 (0.001, 0.52)***	NIR
Caregiver(s)			
Parents and grandparents vs. parents only	NIR	NIR	-0.01 (-0.42, 0.41)
Parents and domestic helper vs. parents only	NIR	NIR	**-0.47 (-0.89, -0.04)***
Parents and others vs. parents only	NIR	NIR	-0.09 (-0.47, 0.29)
Parenting style			
Mothers			
Authoritative	NIR	NIR	-0.08 (-0.38, 0.22)
Authoritarian	NIR	NIR	0.25 (-0.02, 0.51)
Permissive	NIR	NIR	-0.09 (-0.35, 0.18)
Fathers			
Authoritative	NIR	NIR	NIR
Authoritarian	NIR	NIR	NIR
Permissive	NIR	NIR	NIR
Parental bonding			
Mothers			
Care	NIR	0.02 (-0.01, 0.05)	NIR
Overprotection	NIR	0.01 (-0.02, 0.04)	NIR
Fathers			
Care	NIR	NIR	NIR
Overprotection	NIR	NIR	NIR
Child-related factors (Proximal factors)			
Weight status			
Underweight vs. healthy weight	NIR	-0.40 (-0.80, 0.005)	NIR
Overweight vs. healthy weight	NIR	-0.15 (-0.50, 0.19)	NIR
Contextual activities			
Active transport (h/day)	NIR	**0.57 (0.33, 0.82)***	**0.46 (0.21, 0.70)***

Table 2 (continued)

	"High snacks and processed food" pattern	"Balanced" pattern	"Mixed" pattern
Leisure sports (h/day)	NIR	**0.32 (0.19, 0.45)***	**0.19 (0.07, 0.32)***
Screen-viewing while travelling (frequency/day)	NIR	**-0.33 (-0.59, -0.06)***	0.23 (-0.03, 0.50)
Screen-viewing during an eating or drinking occasion (frequency/day)	**0.40 (0.24, 0.57)***	-0.14 (-0.28, 0.01)	0.14 (-0.01, 0.29)
Outdoor time (h/day)	NIR	0.02 (-0.13, 0.17)	0.15 (-0.001, 0.29)
Educational activities outside of school (h/day)	NIR	**0.26 (0.18, 0.33)***	**-0.07 (-0.14, -0.001)***
Consumed breakfast vs. no breakfast	NIR	NIR	NIR

NIR: Not included in final hierarchical regression; variables with $p>0.10$ in the univariate analyses (Supplementary Table 2) were not included in the final three-stage hierarchical regression analyses. Asterisks (*) denote statistically significant associations at 5% level of significance ($p<0.05$)

were more adherent to the "balanced" pattern. Children who were cared for by parents and domestic helper(s) were less adherent to the "mixed" pattern, compared to those who were cared for by their parents only (β=-0.47, 95% CI -0.89, -0.04). Mother's physical activity, parenting style, and parental bonding were not associated with either of the lifestyle patterns.

Among the proximal factors, eating and drinking while screen-viewing (β=0.40, 95% CI 0.24, 0.57) was associated with greater adherence to the "high snacks and processed food" pattern. Active transport (β=0.57, 95% CI 0.33, 0.82), leisure sports (β=0.32, 95% CI 0.19, 0.45), and educational activities outside of school (β=0.26, 95% CI 0.18, 0.33) were positively associated, and screen-viewing while travelling (β=-0.33, 95% CI -0.59, -0.06) was negatively associated with adherence to the "balanced" pattern. Finally, active transport (β=0.46, 95% CI 0.21, 0.70) and leisure sports (β=0.19, 95% CI 0.07, 0.32) were positively associated with adherence to the "mixed" pattern, whereas educational activities outside of school was negatively associated with this pattern (β=-0.07, 95% CI -0.14, -0.001). Outdoor time and breakfast consumption were not associated with either of the lifestyle patterns.

Sensitivity analyses revealed that imputation of missing data, even for variables with high missingness, did not alter our conclusions; findings were by and large similar, and estimates were of a similar direction (data not shown).

Discussion

Our study is unique in that we characterised the lifestyle patterns of the less explored Asian children population in Singapore using a set of 11 input variables comprising both diet- and movement-related behaviours, and examined the correlates of their lifestyle patterns by accounting for the potential interrelation between the various factors investigated using a hierarchical regression approach. We identified three data-driven lifestyle patterns among children aged 10 years in Singapore, classified as "high snacks and processed food", "balanced" and "mixed", and found that some but not all distal, intermediate, and proximal factors were associated with children's lifestyles, which will be discussed in detail below.

A recent systematic review summarised the lifestyle patterns of children aged 10 to 19 years identified in previous studies, namely completely healthy or unhealthy, predominantly healthy or unhealthy, and mixed patterns [7]. Findings of our study were in line with others in that children's lifestyle patterns can generally be classified as healthy or less healthy, with a mixed pattern comprising healthy and unhealthy behaviours. As the "balanced" pattern was the more health-promoting of three patterns identified in the present study, correlates of this pattern are discussed in detail; the correlates of the "high snacks and processed food" and "mixed" patterns will be discussed more briefly.

The "balanced" pattern in our study was characterised by lower screen-viewing and higher consumption of fruits, vegetables, wholegrains, and dairy, in line with general health promoting recommendations for children in Singapore [24]. Of the distal factors, it was observed that girls were more adherent to this "balanced" pattern, compared to boys. Our finding on differences in lifestyle patterns between boys and girls were mostly similar to that of previous studies in children aged five to 18 years [4, 8]; D'Souza and colleagues summarised that boys tended to have higher physical activity along with high or low sedentary behaviour and unhealthier diets, while girls tended to be more sedentary, had lower physical activity but had healthier diets [8]. The sex-based difference in dietary intakes is interesting as this difference was not present within the same GUSTO cohort at an earlier timepoint (age five years) [10]; there was no significant difference in food intakes between boys and girls [10] at age five years. Previous studies have suggested that adolescent females (age 15 years) tended to have better nutrition knowledge, and that females generally were more conscious in engaging in healthier dietary practices [33, 34]. Girls and boys (age six to 18 years) also differed in terms of outcome expectations (e.g. health- versus weight-related motivation for healthy eating) and susceptibility to peer influence [35]. Collectively, these may explain the differences we see in the children of the present study compared to the earlier timepoint as these factors could be more pronounced between the sexes with age and cognitive development [35].

In contrast, girls and boys of the same cohort were previously reported to differ in screen-viewing durations [10] and movement behaviour profiles [36] at earlier timepoints; boys had higher screen-viewing than girls at age five years, and were more active and had less sleep than girls at age eight years. Given the availability of data at multiple time points in the same cohort, longitudinal studies tracking the diet, movement behaviours and/or lifestyle patterns between boys and girls are warranted to confirm and explain these temporal trends.

Additionally, we found that children of parents with a lower level of educational attainment were less adherent to the "balanced" pattern and therefore had unhealthier lifestyles compared to children of parents with higher educational attainment, in line with the wealth of literature exemplifying the associations between SES (most commonly assessed using parental education as proxy) and lifestyle patterns [8]. The associations have been attributed to those of lower SES having less knowledge about and accessibility to healthier options (e.g. high quality diets) [37], as well as less opportunities for family routines that are otherwise associated with positive health behaviours [38]. Our findings further reiterate and highlight that those of lower socio-economic backgrounds are at greater risk of unhealthy lifestyles, even children, warranting whole-of-system efforts to understand the drivers behind their lifestyle behaviours and the development of targeted interventions to bridge the gap in lifestyle practices.

In terms of intermediate factors, we observed that children of mothers with higher diet quality were more adherent to the "balanced" pattern. The close similarities between child and parental diet have been demonstrated extensively, in part due to parental modelling directly influencing their child's dietary knowledge, perceptions, attitudes, preferences and therefore, consumption [39]. These reinforce that future interventions should consider targeting parents, such that parents have healthier lifestyles and can be role models to encourage and foster healthier habits in their children [15].

We identified various proximal factors associated with children's lifestyle. In the present study, weight status was not associated with either of the lifestyle patterns, including the "balanced" pattern. This may be attributed to existing lifestyle counselling programs for overweight children in Singapore [40], and consequently the awareness of healthier lifestyle patterns in overweight children. Previous studies that were mostly cross-sectional by design found strong associations between unhealthy lifestyle patterns and adiposity or overweight/obesity in children [5, 7, 8], which differs from findings of the present study. Cross-sectional studies limit causal inferences as the relationship between weight status and lifestyle patterns may be bi-directional, attenuating observable relationships between these variables. Longitudinal studies to confirm associations between weight status and children's lifestyle behaviours are required.

Contextual activities associated with adherence to the "balanced" pattern were the engagement in more active transport, more leisure sports, less frequent screen-viewing while travelling and more educational activities outside of school. These provide additional information to the interpretation of the pattern, such that to promote adherence to the "balanced" pattern, children can be encouraged to engage in active transport, beyond conventional physical activities like sports. While information on what the children did on their devices while travelling was not collected, we presume screen-viewing while travelling to be passive in nature. Passive screen-viewing has notable ramifications for child outcomes, and as mobile device use increases, how these children experience screen time such as where and when becomes boundless [41], necessitating public health messages promoting healthier lifestyles that encourage the limiting passive screen-viewing that occur concurrently with other activities. We also observed positive associations between engagement in educational activities outside of school and adherence to the "balanced" pattern. This may be explained by these educational activities displacing after school hours, such that less time is available for screen-viewing among children that were more adherent to this pattern.

We found few intermediate factors associated with lifestyle patterns. Only being cared for by both parents and domestic helpers was associated with adherence to the "mixed" pattern; no association existed between parenting style or parental bonding and children's lifestyle patterns. The literature suggests strong associations between these variables and the lifestyle behaviours of children, yet our present study does not support this; among studies in children of a similar age identified in the review by Young and colleagues, having grandparents in caregiving roles alluded to poorer dietary intakes among children as grandparents tended to be more permissive and indulgent [42]. Previous studies also found strong evidence of the role of parents on their child's lifestyle behaviours in that authoritative, warm, and responsive parenting practices were positively associated with health-promoting behaviours in children [43]. To our knowledge, there are few studies tracking the degree of influence parents and caregivers have on children's lifestyle behaviours as children grow older, warranting longitudinal studies to bridge this gap. There is also a lack of studies investigating the influence of domestic helpers on children's lifestyle, limiting our ability to compare our findings. We postulate that domestic helpers can ease the burden on parents in child caregiving, allowing for greater control within the home environment to provide healthier meals and limit the child's opportunities for meals outside of home which may comprise SSB and fast foods. Further, domestic helpers may supervise children when they go outdoors, mitigating parents' concerns regarding safety when their child goes out to play or exercise [44], allowing for more opportunities for physical activity. The present study did not examine the responsibilities of the domestic helper in relation to child caregiving (e.g. household chores, meal preparation, enabling and restricting children's engagement in certain activities, et cetera); as dual-income households and engagement of domestic helpers become more prevalent in high-income countries like Singapore [45], future studies examining the influence of having a domestic helper on children's lifestyle behaviours are warranted.

It is also worth noting that older children such as those of the present study may be entering a developmental phase wherein they perceive greater self-autonomy and begin making their own lifestyle choices [46]. While parents (and caregivers) maintain a crucial role in the home environment [44, 47], children of this age reportedly begin performing certain behaviours without their parents' knowledge as they spend more time outside of home [47], potentially attenuating the influence of parents and caregivers on the child's lifestyle. Instead, as children grow older, their desire to be viewed favourably by their peers and role of peers in their lifestyle choices increases [48]. The lack of strong association between parent-related influences on children's lifestyle suggests that for older children, it may be worth engaging the social groups of children in intervention strategies that address unhealthy lifestyle patterns.

We briefly summarise the findings of the remaining two patterns. In our study, the "high snacks and processed food" pattern was characterised by higher intakes of sweet and savoury snacks and processed foods. It was observed that girls and those with higher screen-viewing during an eating and drinking occasion were more adherent to this pattern.

The "mixed" pattern was characterised by higher engagement in MVPA but lower intakes of vegetables, and higher intakes of SSB and fast food. Children of Malay ethnicity were more adherent to the "mixed" pattern compared to their Chinese counterparts. The observed ethnic-based differences were in line with previous reports on the local Malay population throughout the life course in that people of Malay ethnicity tend to have unhealthier diets [49], strengthening the rationale for focusing public health interventions in this community, even children, to encourage healthy dietary and lifestyle to mitigate the risk of poor outcomes. Engagement in active transport and leisure sports were also positively associated with the "mixed" pattern, facilitating interpretation of this pattern.

Collectively, these findings seek to provide direction for future lifestyle interventions aimed at improving the lifestyles of children in an Asian population. We found that boys, Malays, those of lower SES, and those of mothers with poorer diet quality should be prioritised, suggesting the need for targeted, tailored interventions as these groups tended to have unhealthier lifestyles. Our findings regarding the contextual activities shed light on the contexts that can be incorporated in lifestyle intervention strategies. For example, public health messaging could encourage active transport to help children be more active, or bring awareness to passive screen viewing such as while travelling or during meals to address these emerging behavioural concerns integral in children's lifestyles.

This is the first study, to our knowledge, investigating a wide range of sociodemographic, parent- and child-related factors in relation to children's lifestyle patterns comprising diet- and movement-related variables in an Asian setting. In our analyses, we also accounted for the interrelatedness of these variables using the hierarchical regression analysis method proposed by Victora and colleagues for epidemiological studies to provide more accurate estimates of association [19]. Our findings bridge important gaps in existing literature to provide information for the development of future lifestyle interventions for children, both locally and regionally. Several limitations of our study to be acknowledged. Though the MEDAL self-report tool used in the present study has demonstrated acceptable usability and validity among children from the same population and age group [21–23], the reliance on children's self-reports on their dietary intakes and activities are subject to recall bias [22, 23], therefore dietary intakes and engagement in specific activities may be under or over-reported. However, MEDAL allowed information on important behavioural variables to be collected without incurring substantial burden for participants and researchers [21]. The information collected included dietary intakes, screen-viewing and the contexts of which, the distinction of specific domains of physical activity (e.g. active sport and leisure sport) and time spent in educational activities [21], which cannot be otherwise collected through objective assessments without laborious research processes (e.g. accelerometers, wearable cameras). We acknowledge that the input variables used to derive the lifestyle patterns of children were mostly comprised of diet-related variables, with the movement behaviours being represented by only three variables; future studies could consider other movement behaviour-related aspects of children's lifestyle. Notwithstanding, the variables selected in the present study were based on available data for the cohort, avoided the omission of either diet or movement behaviours when examining lifestyles, and were in line with national guidelines in Singapore for diet and activities for children and adolescents [24]. Thirdly, there were significant missing data, particularly for parenting style, parental bonding, and child's caregiver information, however, sensitivity analyses revealed that imputation of missing data did not alter our conclusions. Fourthly, while we considered an extensive range of factors that could have influenced children's lifestyle patterns, like many cross-sectional and observational studies, we cannot determine causality or rule out residual confounding. We also note that around a third of the participants followed up at age 10 were excluded from analyses because they did not complete at least two valid days of recording on MEDAL, and included and excluded participants differed in characteristics (Supplementary Table 3). The reduced sample also underpowered our analysis to investigate variables that had high homogeneity (e.g. maternal marital status and smoking habit) and perform factor analysis like PCA (KMO = 0.56). It is also worth noting that the overall GUSTO cohort is not representative of the Singaporean population, in that Malay and Indians were purposefully overrecruited, and that recruited mothers were more likely to hold a university degree, compared to the general population [20]. Additionally, not all questionnaires used were validated within the present population. Hence our findings should be interpreted and generalised with caution, but nonetheless provides valuable insights.

Conclusion

Considering both diet and movement behaviour aspects, we found three distinct lifestyle patterns among children in Singapore aged 10 years. Our study is unique in that we examined the correlates of the lifestyle patterns by accounting for the potential interrelation between the various factors investigated. These findings shed light and provide direction for future interventions aiming to improve the lifestyles of these children by elucidating the groups that should be prioritised. Specifically, we identified that differentiated and tailored interventions prioritising boys, Malays, those of lower SES, and those of mothers with poorer diet quality are needed. Findings on the contextual activities associated with children's lifestyles provide additional information on the possible public health messages that could encourage balanced lifestyles.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-19669-2.

Supplementary Material 1

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Author contributions

MFFC and FMR designed the research; YSC, KMG, KHT, and JGE designed and led the GUSTO study; JYT, MC, and PN conducted research and/or collected the GUSTO data; SYXT performed the statistical analysis with guidance from AC, BCT and MF-FC; SYXT drafted the manuscript; BCT, MF-FC, and FMR critically reviewed the manuscript; all authors read and approved the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the National Health Care Group Domain Specific Review Board (reference D/09/021) and the SingHealth Centralized Institutional Review Board (reference 2009/280/D). All participants provided written informed consent at enrolment.

Consent for publication
Not applicable.

Competing interests
KMG and YSC have received reimbursement for speaking at conferences sponsored by companies selling nutritional products. KMG and YSC are part of an academic consortium that has received research funding from Abbott Nutrition, Nestec, and Danone. All other authors report no conflicts of interest.

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